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# Soil Health Indicators & Lab Procedures for Assessing Soil Health

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## USDA Releases Standard Indicators and Laboratory Procedures to Assess Soil Health

Federal Register / Vol. 83, No. 179 / Friday, September 1

DEPARTMENT OF AGRICULTURE

Natural Resources Conservation Service

[Docket No. NRCS–2018–0006]

**Notice of Recommended Standard Methods for Use as Soil Health Indicator Measurements**

**AGENCY:** Natural Resources Conservation Service (NRCS), U.S. Department of Agriculture (USDA).

**ACTION:** Notice of availability of proposed technical note "Recommended Soil Health Indicators and Associated Laboratory Procedures" for public review and comment.

**SUMMARY:** *Notice is hereby given of the* intention of NRCS to issue a technical note on a group of recommended standard methods for soil health indicators selected by a collaborative multi-organizational effort, as described in the document. USDA/NRCS and partner efforts to assess soil health problems and impacts of management nationally, as part of conservation planning and implementation, will be facilitated if soil health indicators are measured using a standard set of methods. Soil health is defined as the capacity of the soil to function as a vital living ecosystem to sustain plants, animals, and humans. Six key soil physical and biological processes were identified that must function well in a healthy soil, and therefore would especially benefit from measurement methods standardization: (1) Organic

and Sasser 2012). Standard operating procedures to be used in laboratories have been provided in the appendices.

**DATES:**

*Applicable Date:* This is Applicable September 14, 2018.

*Comment Date:* Submit comments on or before December 13, 2018. A final version of this technical note will be published after the close of the 90-day period and after consideration of all comments.

**ADDRESSES:**

*Obtaining Documents:* You may download the draft Technical Note at *https://go.usa.gov/xUFJE.*

Comments should be submitted, identified by Docket Number NRCS–2018–0006, using any of the following methods:

- *Federal eRulemaking Portal: http://www.regulations.gov.* Follow the instructions for submitting comments.
- *Mail or hand-delivery:* Public Comments Processing, Attention: Regulatory and Agency Policy Team, Strategic Planning and Accountability, Natural Resources Conservation Service, 5601 Sunnyside Avenue, Building 1–1112D, Beltsville, Maryland 20705.

NRCS will post all comments on *http://www.regulations.gov.* In general, personal information provided with comments will be posted. If your comment includes your address, phone number, email, or other personal identifying information (PII), your comments, including PII, may be available to the public. You may ask in your comment that your PII be withheld

- **USDA**
  - ✓ **NRCS**
  - ✓ **ARS**
  - ✓ **NIFA**
- **Comments by Dec 13 2019**

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## Soil Health

**Soil Health**: the continued capacity of the soil to function as a *vital living ecosystem* that sustains plants, animals, and humans

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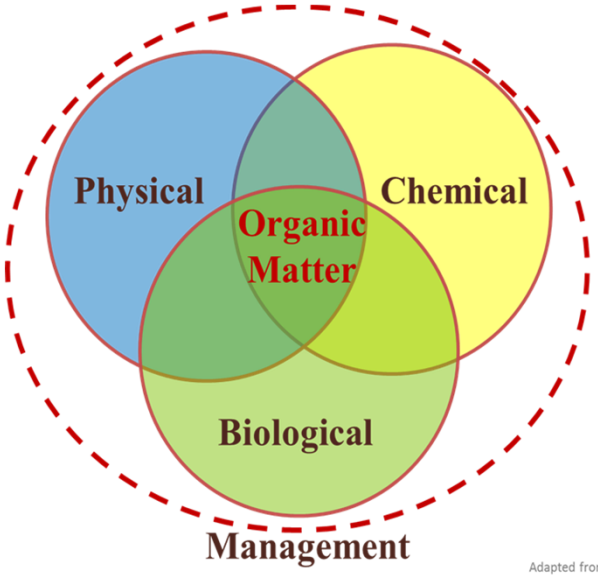
## Soil Health




Adapted from Cornell University

## Soil Health Testing

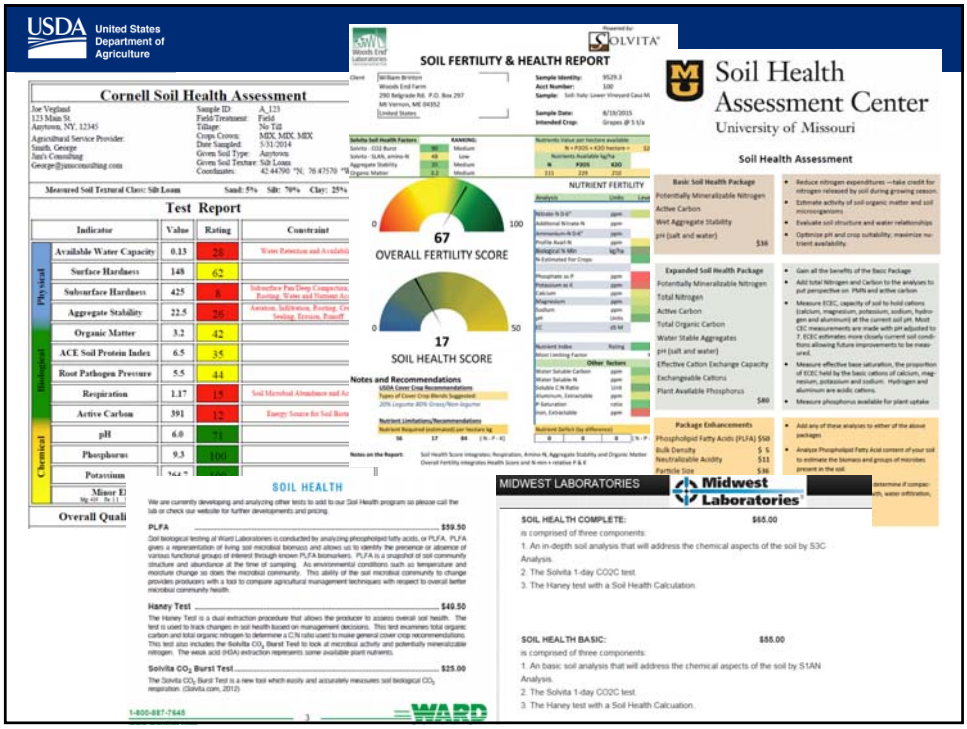
- Soil treated and evaluated as living organism
- Few offerings but lots of interest
- Difficult to interpret
- Not standardized
- No similar “packages”

## Soil Health Assessment

- Standards for ‘current best available’ indicators and methods to assess soil health resource concerns
- Potential for use in monitoring ΔSH nationally
- EQIP and CSP

Soil Quality Assessments of the 90s


Soil Health Assessments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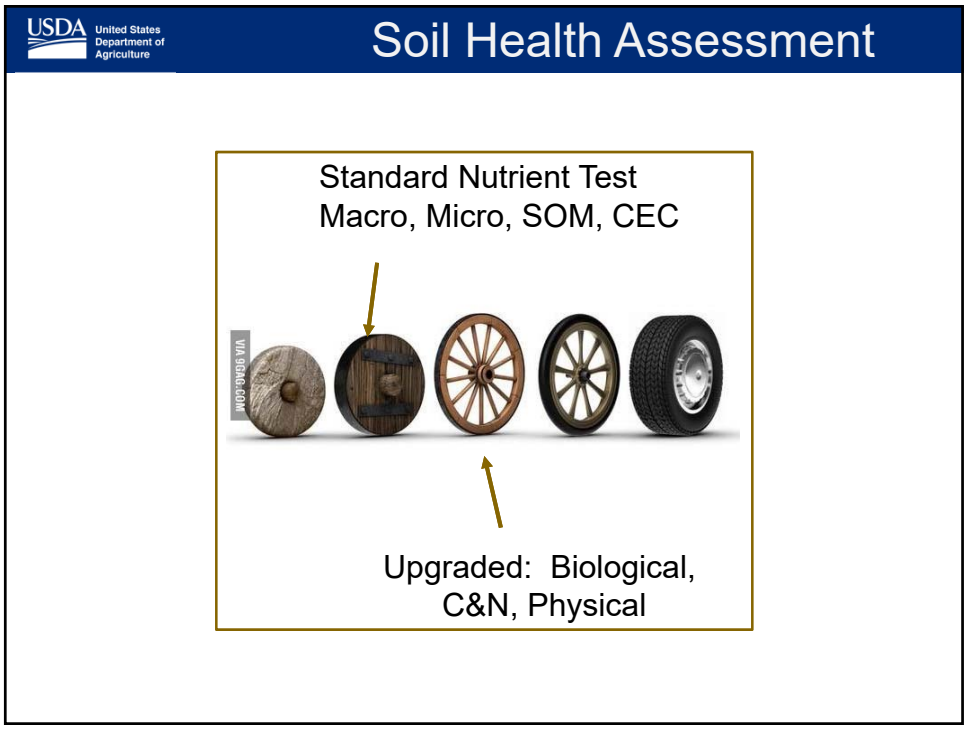
Cornell Soil Health Assessment
Test Report
SOIL FERTILITY & HEALTH REPORT
SOLVITA
67
OVERALL FERTILITY SCORE
17
SOIL HEALTH SCORE
Soil Health Assessment Center
University of Missouri
Soil Health Assessment
SOIL HEALTH
MIDWEST LABORATORIES
Midwest Laboratories
SOIL HEALTH COMPLETE: $65.00
SOIL HEALTH BASIC: $55.00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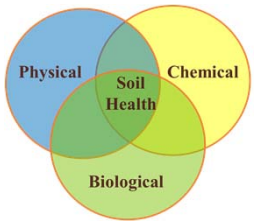
Soil Health Assessment
Standard Nutrient Test
Macro, Micro, SOM, CEC
VIA 9GAG.COM
Upgraded: Biological,
C&N, Physical

## Criteria for Indicators

– Diverse processes
– Sensitive management but robust
– Ability to show short term change
– Standardized




– *Easy and inexpensive to sample & measure*
– *Repeatable*
– *Minimal investment*
– *Interpretations easy, accessible and agreed-upon*
– ***Actionable:** provide management recommendations*

(Doran et al., 1994; Larson and Pierce, 1991; Mausbach and Seybold, 1998; Moebius et al., 2007; Bastida et al., 2008; Moebius-Clune 2010)

## Indicator Tiers

**Tier 1**

- Defined regionally and by soil groupings across nation
- Have thresholds to indicate "Poor", "Adequate", "Good" that are outcome based (i.e. yield, environmental, etc.)
- Management can be suggested to improve soil functioning

**Tier 2**

- Know trends/directionality, potential ranges in some regions, not national calibrated
- Do not know thresholds
- Have some idea of which management practices can change indicator and processes it informs us about

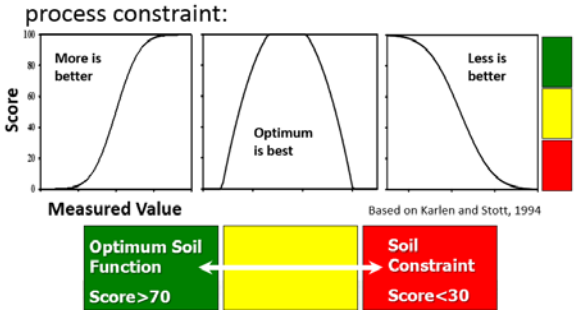
**Tier 3**

- Have potential
- More work needed

## Scoring Methods

**Directionality**

3 types of Scoring Functions interpret degree of soil process constraint:

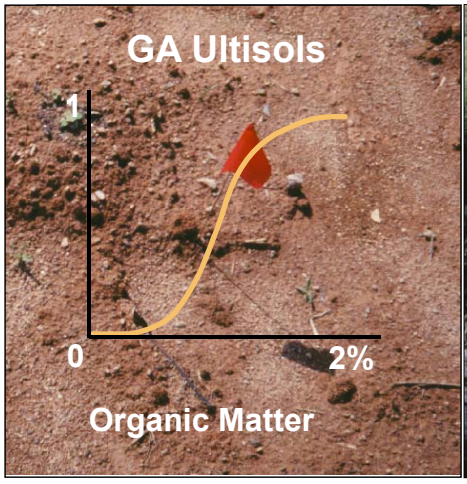


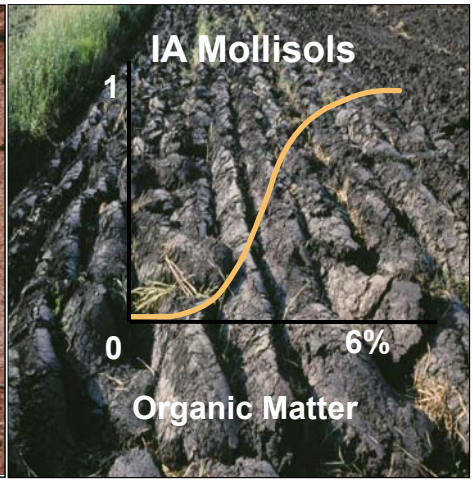

**Calibration**

- Calculate mean and standard deviation within a group
- Assess where individual falls in frequency distribution
- **Can be done based on a regional dataset before outcome thresholds are identified**

## Calibration & Interpretation

- Indicator interpretation via soil based scoring functions
- Soil, climate and cropping system



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## Processes

### Soil Organic Matter Accumulation

- Critically important for nutrient storehouse, soil structure, and support of the underground biota, among other impacts
- Tier 1: Soil Organic Carbon (dry combustion)
- Tier 2: Loss on Ignition

### Nutrient Availability

- Tier 1: NPK – Major plant nutrients
- Tier 2: Minor and Trace elements

### Chemical Reactivity

- Tier 1: pH
- Tier 2: Salinity / Sodicity

### Soil Structure / Water Partitioning

- Tier 2: Macroaggregate Stability

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## Processes

### General Microbial Activity

- Tier 2: Short-term Carbon Mineralization
- Tier 2: Metabolic (Enzyme) Activity

### Available Carbon Source

- Tier 2: Active Carbon (permanganate oxidizable)

### Bioavailable Nitrogen

- Tier 2: Soil Protein concentration
- *Potentially mineralizable nitrogen?*

### Microbial Community and Diversity

- Tier 2 or 3: Phospholipid Fatty Acid Profiles (PLFA)
- Tier 3: Many methods show promise, but still require a lot of work before they are ready for deployment to soil test labs.

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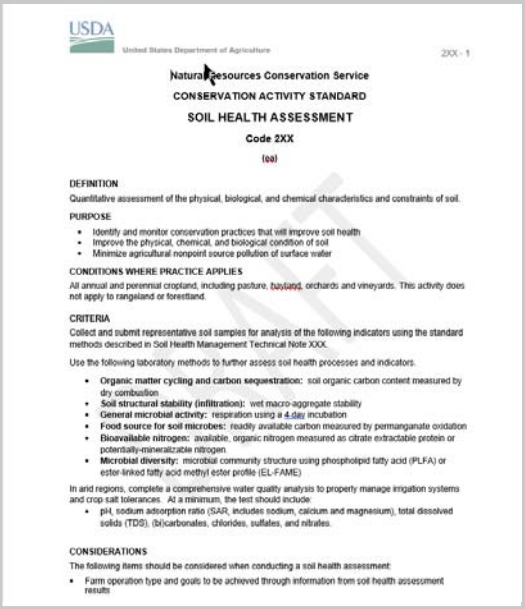
# Integration in NRCS

Soil Health Monitoring Activity (2XX)



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2XX - 1

Natural Resources Conservation Service

CONSERVATION ACTIVITY STANDARD

SOIL HEALTH ASSESSMENT

Code 2XX

(ac)

DEFINITION

Quantitative assessment of the physical, biological, and chemical characteristics and constraints of soil.

PURPOSE

- Identify and monitor conservation practices that will improve soil health
- Improve the physical, chemical, and biological condition of soil
- Minimize agricultural nonpoint source pollution of surface water

CONDITIONS WHERE PRACTICE APPLIES

All annual and perennial cropland, including pasture, hayland, orchards and vineyards. This activity does not apply to rangeland or forestland.

CRITERIA

Collect and submit representative soil samples for analysis of the following indicators using the standard methods described in Soil Health Management Technical Note XXX.

Use the following laboratory methods to further assess soil health processes and indicators.

- **Organic matter cycling and carbon sequestration:** soil organic carbon content measured by dry combustion
- **Soil structural stability (infiltration):** wet macro-aggregate stability
- **General microbial activity:** respiration using a 4-day incubation
- **Food source for soil microbes:** readily available carbon measured by permanganate oxidation
- **Bioavailable nitrogen:** available, organic nitrogen measured as citrate extractable protein or potentially-mineralizable nitrogen
- **Microbial diversity:** microbial community structure using phospholipid fatty acid (PLFA) or ester-linked fatty acid methyl ester profile (EL-FAME)

In arid regions, complete a comprehensive water quality analysis to properly manage irrigation systems and crop salt tolerances. At a minimum, the test should include:

- pH, sodium adsorption ratio (SAR, includes sodium, calcium and magnesium), total dissolved solids (TDS), (bi)carbonates, chlorides, sulfates, and nitrates.

CONSIDERATIONS

The following items should be considered when conducting a soil health assessment:

- Farm operation type and goals to be achieved through information from soil health assessment results

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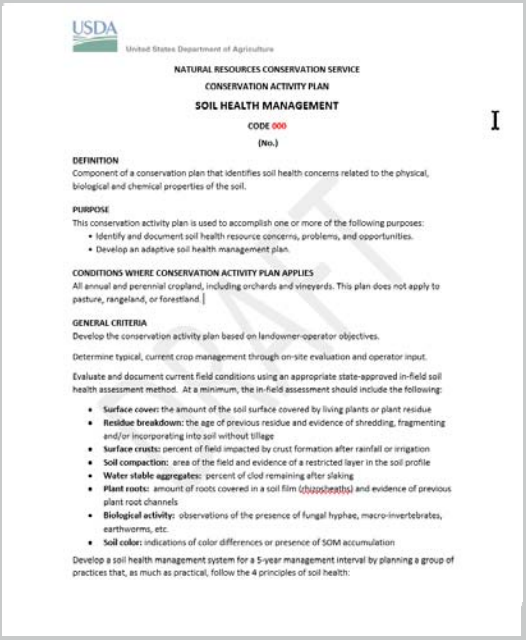
# Integration in NRCS

Soil Health Management CAP (1XX)

Coupled with in-field semi-quantitative assessment



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NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION ACTIVITY PLAN

SOIL HEALTH MANAGEMENT

CODE 000

(No.)

DEFINITION

Component of a conservation plan that identifies soil health concerns related to the physical, biological and chemical properties of the soil.

PURPOSE

This conservation activity plan is used to accomplish one or more of the following purposes:

- Identify and document soil health resource concerns, problems, and opportunities.
- Develop an adaptive soil health management plan.

CONDITIONS WHERE CONSERVATION ACTIVITY PLAN APPLIES

All annual and perennial cropland, including orchards and vineyards. This plan does not apply to pasture, rangeland, or forestland.

GENERAL CRITERIA

Develop the conservation activity plan based on landowner-operator objectives.

Determine typical, current crop management through on-site evaluation and operator input.

Evaluate and document current field conditions using an appropriate state-approved in-field soil health assessment method. At a minimum, the in-field assessment should include the following:

- **Surface cover:** the amount of the soil surface covered by living plants or plant residue
- **Residue breakdown:** the age of previous residue and evidence of shredding, fragmenting and/or incorporating into soil without tillage
- **Surface crusts:** percent of field impacted by crust formation after rainfall or irrigation
- **Soil compaction:** area of the field and evidence of a restricted layer in the soil profile
- **Water stable aggregates:** percent of clod remaining after slaking
- **Plant roots:** amount of roots covered in a soil film (rhizosheaths) and evidence of previous plant root channels
- **Biological activity:** observations of the presence of fungal hyphae, macro-invertebrates, earthworms, etc.
- **Soil color:** indications of color differences or presence of SOM accumulation

Develop a soil health management system for a 5-year management interval by planning a group of practices that, as much as practical, follow the 4 principles of soil health:

## Organic Matter & C Cycling

| SOIL PROCESS | SOIL HEALTH INDICATORS | METHODS CONSIDERED | NOTES |
|---|---|---|---|
| Organic Matter Cycling & C Sequestration | Soil Organic Carbon Content | Dry Combustion | **Recommended Method**. Nelson and Sommers (1996). The standard operating procedure (SOP) is from Soil Survey Staff (2014), pp. 464–471. If the soil sample is above pH 7.2, then it must be corrected to inorganic carbon (Sherrod et al. 2002). |
| | | Wet Oxidation | Gives same numbers as dry combustion, but has chemical wastes and is more labor intensive. |
| | Mass Loss | Loss-on Ignition | Used by many soil test labs, but must be re-calibrated for each small region (several regions per state). |

## Structural Stability or Infiltration

| | | | |
|---|---|---|---|
| Soil Structural Stability (Infiltration) | Aggregation | ARS Wet Macroaggregate Stability | **Recommended Method.** Kemper & Rosenau (1986). Subsequently published by Nimmo and Perkins (2002). SOP from Mikha and Rice (2004). |
| | | NRCS Wet Aggregation | Based on Kemper and Rosenau (1986), this method pre-wets the samples (Soil Survey Staff 2014, pp. 213–216). |
| | | Cornell Sprinkle Infiltrometer | Schindelbeck et al. (2016). Values from this method have not yet been correlated with the wet-sieve method. |

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# Respiration

| SOIL PROCESS | SOIL HEALTH INDICATORS | METHODS CONSIDERED | NOTES |
|---|---|---|---|
| General Microbial Activity | Short-term C mineralization (a.k.a. respiration) | A 4-day soil incubation | **Recommended Method.** Schindelbeck et al. (2016). A 4-day soil incubation (CO2 measured by electrical conductivity, gas chromatography, or titration). |
| | | $CO_2$, respired, 24-hr | Like the previous method, but with a shorter incubation time, e.g., Haney et al. 2017, Solvita®, or other 24-hr methods). Often has high variability amongst replicates. |

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# Enzyme Activity

| SOIL PROCESS | SOIL HEALTH INDICATORS | METHODS CONSIDERED | NOTES |
|---|---|---|---|
| General Microbial Activity | Enzyme activity<br><br>A suite of enzymes is recommended | β-Glucosidase | **Recommended Method.** Eivazi and Tabatabai (1988) as presented by Deng and Popova (2011). Also in Soil Survey Staff (2014), pp. 513–518. Involved in the C-cycle. |
| | | N-acetyl-β-D-glucosaminidase (NAG) | **Recommended Method.** Parham and Deng (2000) as presented by Deng and Popova (2011). Involved in the C- & N-cycles. |
| | | Phosphomono-esterases (acid/alkaline phosphatase) | **Recommended Method.** Eivazi and Tabatabai (1977) as presented by Acosta-Martínez and Tabatabai (2011). Involved in the P-cycle. Both present in all soils, with acid phosphatase dominating in soils ≤7.2 and alkaline phosphatase in soils >7.2. |
| | | Arylsulfatase | **Recommended Method.** Tabatabai (1970) presented by Klose et al. (2011). Involved in the S-cycle. |
| | Another 10 enzymes were considered, but for various reasons they were eliminated (couldn't be done on air-dried samples; not enough papers in the literature to ascertain trends and thresholds; too expensive). | | |

## Carbon Food Sourcs

| SOIL PROCESS | SOIL HEALTH INDICATORS | METHODS CONSIDERED | NOTES |
|---|---|---|---|
| Carbon Food Source | Readily Available Carbon Pool | Permanganate Oxidizable C (POXC) | **Recommended Method.** Weil et al. 2003. SOP from Schindelbeck et al. 2016. Also in Soil Survey Staff (2014), pp. 505–509. |
| | | Particulate Organic Matter | Good method. The fraction is operationally defined, with many methods in use. Currently not appropriate for soil test labs. |
| | | 28-day C Mineralization | Too long (same method as the 4-day method, but has a longer incubation) |
| | | Cold/Hot Water Extractable Organic C (WEOC) | Cold WEOC (Haney et al. 2017). Hot WEOC (Ghani et al. 2003). Gives a snapshot of C availability in the soil solution at sampling time. May not reflect total pool. |
| | | Soluble Carbohydrates | An older method no longer in wide use. |
| | | Substrate-induced Respiration | Research method; it is labor intensive. |
| | | Microbial Biomass C | Fumigation-incubation or fumigation-extraction. A research method that is time/labor intensive. |

## Bioavailable Nitrogen

| SOIL PROCESS | SOIL HEALTH INDICATORS | METHODS CONSIDERED | NOTES |
|---|---|---|---|
| Bioavailable Nitrogen | Available Organic Nitrogen Pool | Autoclaved Citrate Extractable (ACE) Protein Content | **Recommended Method.** Schindelbeck et al. (2016). Modification, published by Hurisso et al. (2018), from Wright and Upadhyaya (1998). |
| | | Cold Water Extr. Organic N (WEON) | Haney et al. 2017. Not enough data available at this time. |
| | | Correlation with Short-Term C Mineralization | Picone et al. (2002). Has promise but requires more evaluation with broader number of soils and management systems. |
| | | 7-day Anaerobic Pot.Mineralizable Nitrogen (PMN) | Drinkwater et al. (1996). The 7-day incubation is too long for high-throughput labs. |
| | | 28-day Aerobic PMN Incubation | Used in the USDA/ARS Conservation Effects Assessment Projects (CEAP) soil health assessments (e.g., Stott et al. 2011). Too long. |
| | | Illinois Soil N Test (ISNT) | Nitrogen available as amino-sugar (e.g., Sharifi et al. 2007). Measures a constant fraction of total soil N. Usually evaluated against yield rather than soil health. |
| | | β-glucosaminidase activity (NAG) | See soil enzyme activity above |
| | | Protease | Must use fresh soil |

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# Microbial Diversity

| SOIL PROCESS | SOIL HEALTH INDICATORS | METHODS CONSIDERED | NOTES |
|---|---|---|---|
| Microbial Diversity | Community Structure | Phospholipid Fatty Acid (PLFA) Profile | **Recommended Method.** PLFA (Buyer and Sasser 2012). PLFA is an older method. It gives coarse community structural information. |
| | | Ester-Linked Fatty Acid Methyl Ester (EL-FAME) Profile | This is a newer method and less expensive, but is less suitable due to lack of fungal markers |
| | | "Sampling for Life" | **Recommended.** If appropriate storage is available, we recommend archiving samples until newer methods are available. |

# PLFA (2016)

| | Years of CC | | | P-value | |
|---|---|---|---|---|---|
| Biomass, ng/g | 1 or less | 4 or more | SEM | CC | region |
| Total | 1395 | 2107 | 205 | 0.03 | 0.43 |
| Bacteria | 744 | 1128 | 112 | 0.03 | 0.53 |
| Fungi | 86 | 223 | 33.6 | 0.01 | 0.32 |
| Arbuscular Mycorrhizal | 24 | 62 | 11 | 0.04 | 0.48 |
| Saprophytes | 62 | 162 | 26 | 0.02 | 0.32 |
| Protozoa | 6 | 19 | 3 | <0.01 | 0.2 |
| | | | | | |
| Diversity index | 1.35 | 1.56 | 0.056 | 0.02 | 0.41 |
| Fungi to bacteria | 0.116 | 0.194 | 0.025 | 0.05 | 0.58 |

Within No-till fields

Mary Drewnoski, Univ. of Nebraska

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# Methods Technical Note

Federal Register Docket No. NRCS-2018-0006

Download a draft at https://go.usa.gov/xUFJE

Instructions for submitting comments can be found at the Federal eRulemaking Portal: http://www.regulations.gov/

FOR FURTHER INFORMATION CONTACT:

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# Soil Health Indicators/Methods

*Potential Indicators/Methods

| Process | Indicator |
|---|---|
| SOM Cycling | Organic C (dry combustion) |
| Water Partitioning | Macro-aggregate Stability |
| General Microbial Activity | |
| Short term C Mineralization | 4 day respiration |
| Metabolic Activity | β-glucosidase, NAG |
| Carbon Food Source | POXC |
| Bioavailable N | ACE Proteins |
| Microbial Diversity | PLFA/EL-FAME |

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# Metadata Entry Considerations

- Ideally the comprehensive list of metadata will be entered (note that not all are relevant on all fields)
- Some info can be obtained from web soil survey in advance
- GPS essential, allows for further information to be obtained at any time for soil/climate
- Outcome data is the most difficult to obtain, but critical to allow for evaluation of benefits
- Key land history entries for soil health interpretations include residue remaining, presence, diversity, and how long cover crop is used, crop rotation details, perennial vs. annual, organic amendments, fallow period (or conversely how many months there are living roots present), disturbance factor and how long reduced or no-till has been practiced

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